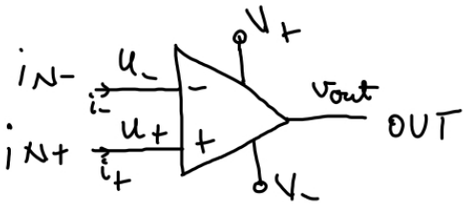
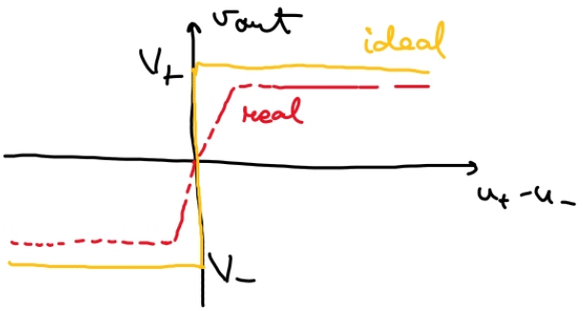
Laborator 6 FMI:

Amplificatorul operațional:

„op-amp", A.O.

A.O. - circuit integrat → tranzistori (BJT, FET)
→ rezistori
→ condensatori





$$v_{out} = A_d (u_+ - u_-)$$

A_d - factorul de amplificare în buclă deschisă („open-loop gain").

Caracteristici A.O. IDEAL:

$A_d = \infty$

$Z_{in} = \infty$

$Z_{out} = 0$

$i_-, i_+ = 0$.

A.O. REAL

$A_d \simeq 10^5$

$Z_{in} \simeq M\Omega$

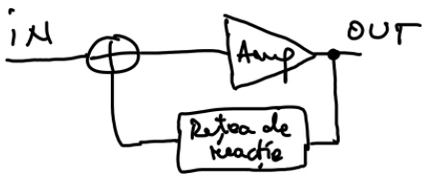
$Z_{out} \simeq 100\ \Omega$

$i_+, i_- \simeq mA - \mu A$

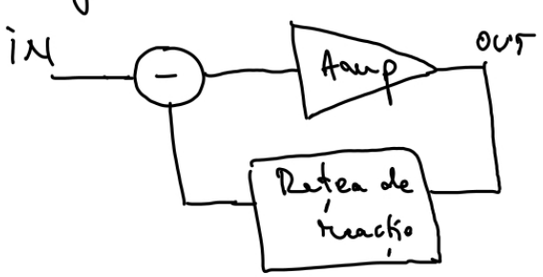
Reacția: („feedback")

consid. A.O. IDEAL

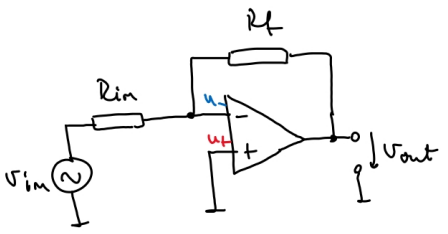
a) pozitivă



b) negativă



1) Conexiunea inversoare:

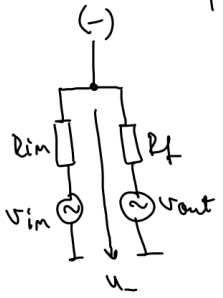


$V_{out} = ? = f(V_{in}, R_f, R_{in})$

$V_{out} = A_{ol}(u_+ - u_-)$; $A_{ol} \to \infty$

$u_+ = 0$

schema echivalentă pt. ix-



T. lui Millman

$$u_{ech} = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \dots + \frac{V_n}{R_n}}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}}$$

T. lui Millman $\Rightarrow$ $u_- = \dfrac{\frac{V_{in}}{R_{in}} + \frac{V_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_f}} = \dfrac{\frac{V_{in}R_f + R_{in}V_{out}}{R_{in}R_f}}{\frac{R_{in}+R_f}{R_{in}R_f}}$

$$u_- = \frac{V_{in}R_f + R_{in}V_{out}}{R_{in}+R_f}$$

$$V_{out} = -A_{ol} \cdot \frac{V_{in}R_f + R_{in}V_{out}}{R_{in}+R_f}$$

$$V_{out}R_{in} + V_{out}R_f = -A_{ol}V_{in}R_f - A_{ol}R_{in}V_{out}$$

$$V_{out}(R_{in}+R_f+A_{ol}R_{in}) = -A_{ol}V_{in}R_f$$

$$V_{out} = -\frac{A_{ol}R_f}{R_{in}+R_f+A_{ol}R_{in}} \cdot V_{in}$$

$$V_{out} = -\frac{A_{ol}R_f}{A_{ol}\left(R_{in} + \frac{R_{in}R_f}{A_{ol}}\right)} V_{in}$$

0

$$V_{out} = -\frac{R_f}{R_{in}} \cdot V_{in}$$

$$V_{out} = A_{inv} \cdot V_{in}$$

$$A_{inv} = -\frac{R_f}{R_{in}}$$

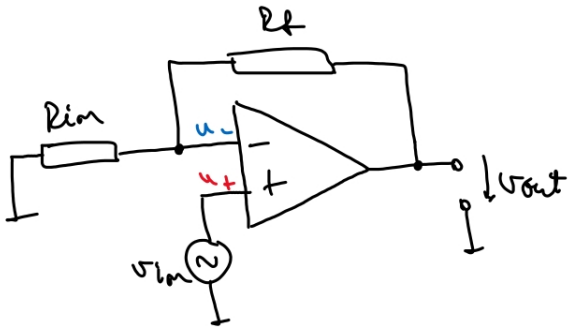
$$u_- = \frac{V_{in}R_f + R_{in}V_{out}}{R_{in}+R_f} = \frac{V_{in}R_f - \frac{R_f}{R_{in}} \cdot R_{in} \cdot V_{in}}{R_{in}+R_f}$$

$u_- = 0$

$u_+ = 0$ $\Rightarrow$

$\Rightarrow$ $u_+ \simeq u_-$

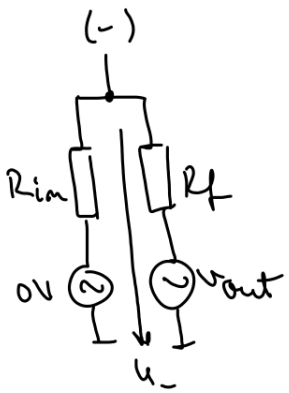
Conexiunea neinversoare:



$v_{out} = ? = f(v_{in}, R_{in}, R_f)$

$u_+ = v_{in}$

schema echivalenta pt. u_-



T. lui Millman:

$$u_- = \frac{\frac{0}{R_{in}} + \frac{v_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_f}}$$

$$u_- = \frac{\frac{v_{out}}{R_f}}{\frac{R_f + R_{in}}{R_f R_{in}}} = \frac{R_{in}}{R_f + R_{in}} \cdot v_{out}$$

$$u_+ = u_- \Rightarrow \quad v_{in} = \frac{R_{in}}{R_f + R_{in}} \cdot v_{out}$$

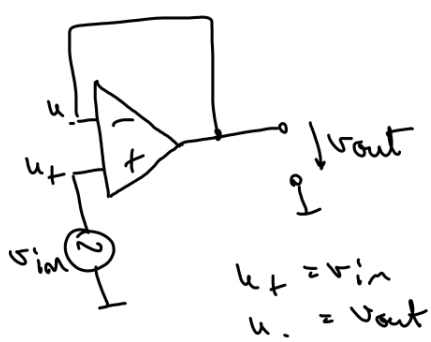
$$v_{out} = \frac{R_f + R_{in}}{R_{in}} \cdot v_{in}$$

$$\boxed{v_{out} = \left(1 + \frac{R_f}{R_{in}}\right) v_{in}}$$

$v_{out} = A_{neinv} \, v_{in}$

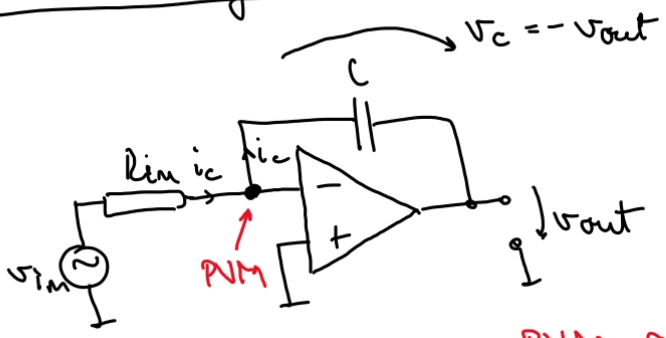
$A_{neinv} = 1 + \frac{R_f}{R_{in}}$

Conexiunea repetoare: „buffer", „voltage follower".



$u_+ = v_{in}$
$u_- = v_{out}$
$\Rightarrow \quad \boxed{v_{out} = v_{in}}$

Conexiunea integratoare:



PVM = punct virtual de masă

Legea lui Ohm pt. capacitați

$$i_c = C \cdot \frac{dv_c}{dt} = -C \cdot \frac{dv_{out}}{dt}$$

$$v_{in} = R_{in} \cdot i_c \Rightarrow i_c = \frac{v_{in}}{R_{in}}$$

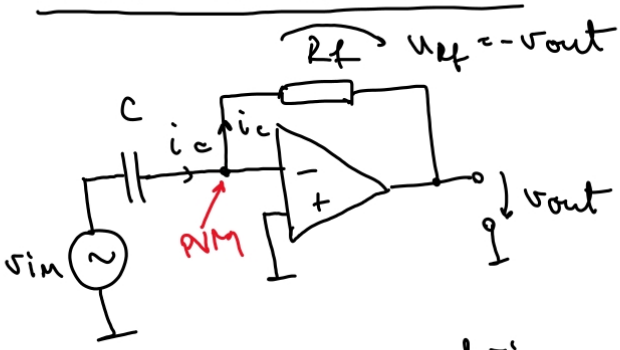
$$\frac{v_{in}}{R_{in}} = -C \cdot \frac{dv_{out}}{dt}$$

$$v_{in}\,dt = -R_{in} C \cdot dv_{out}$$

$$\int (-R_{in}C)\,dv_{out} = \int v_{in}\,dt$$

$$\boxed{v_{out} = -\frac{1}{R_{in}C}\int v_{in}\,dt}$$

Conexiunea derivatoare:



$$i_c = C \cdot \frac{dv_{in}}{dt}$$

$$v_{Rf} = R_f \cdot i_c \Leftrightarrow -v_{out} = R_f \cdot i_c$$

$$i_c = -\frac{v_{out}}{R_f}$$

$$-\frac{v_{out}}{R_f} = C \cdot \frac{dv_{in}}{dt}$$

$$\boxed{v_{out} = -R_f C \cdot \frac{dv_{in}}{dt}}$$